Arts & Science 2D06

Quiz #4 2006 Nov 24 **Name:**

NB: Mark values are given in brackets [ ] beside each problem. Write all your answers on the quiz paper. No books or notes allowed. Time to write quiz: 50 minutes.

Taylor series: $(1+x)^a \simeq 1 + ax$ for small x

Gamma factor: $\gamma = (1 - v^2/c^2)^{-1/2}$ Momentum: $p = \gamma m v$

Lorentz transformation: $x' = \gamma(x - vt)$, $t' = \gamma(t - \frac{v}{c^2}x)$.

Velocity addition: $u' = \frac{(u-v)}{(1-uv/c^2)}$

Rest-mass Energy: $E = mc^2$ Kinetic energy: $K = (\gamma - 1)mc^2$

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1. [3] In 2005, Ontario Hydro supplied a total of $5.65 \times 10^{17} J$ of energy to its customers, added up over the entire year. What "rest mass" is that energy equivalent to?

2. [3] You are on a spaceship travelling away from Earth at speed $0.5c$, and you observe another spaceship passing by you at a speed that *you* measure as $0.5c$. What was the speed of the other ship relative to the Earth?

3. [2] A spaceship travels from Earth to a star 5 light-years away. According to us on Earth, the trip took 8 years. The elapsed time according to clocks on the spaceship was

(i) 5 years (ii) 6.2 years (iii) 8 years (iv) 10.2 years

4. [3] The momentum of a fast-moving particle is three times larger than the Newtonian expression would give. What is its speed?

5. [5] A train with a proper length of 1 km zooms by at $v = 0.95c$ as you stand on the ground and watch it.

(a) What is its measured length, from the reference frame of the ground?

(b) Now do the following "thought experiment". The engineer on the train has a small device at the back end of the train that can reach out and leave a mark on the ground as it goes by. There is an identical device at the front of the train. Suppose the engineer switches on these two devices *simultaneously* (from his point of view!). That is, two marks are left on the ground. *How far apart are these marks, as measured from the ground?* (Hint: define the mark at the back end of the train to be at $x_1 = 0, t_1 = 0$ and $x'_1 = 0, t'_1 = 0$.)

6. [4] A light goes on at ($x_1 = 0, t_1 = 0$), and a bit later on a second light goes on at ($x_2 = 350{,}000$ km, $t_2 = 1.00$ sec). Now suppose that a second reference frame ($x'y'$) travels to the right at speed v.

(a) What is the necessary speed v for which these two events are simultaneous as seen from ($x'y'$)?

(b) Where did the second event occur as seen from ($x'y'$)?

[20] total marks